DARPA MEMS Program and Application in Space

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Outline

MTO MEMS

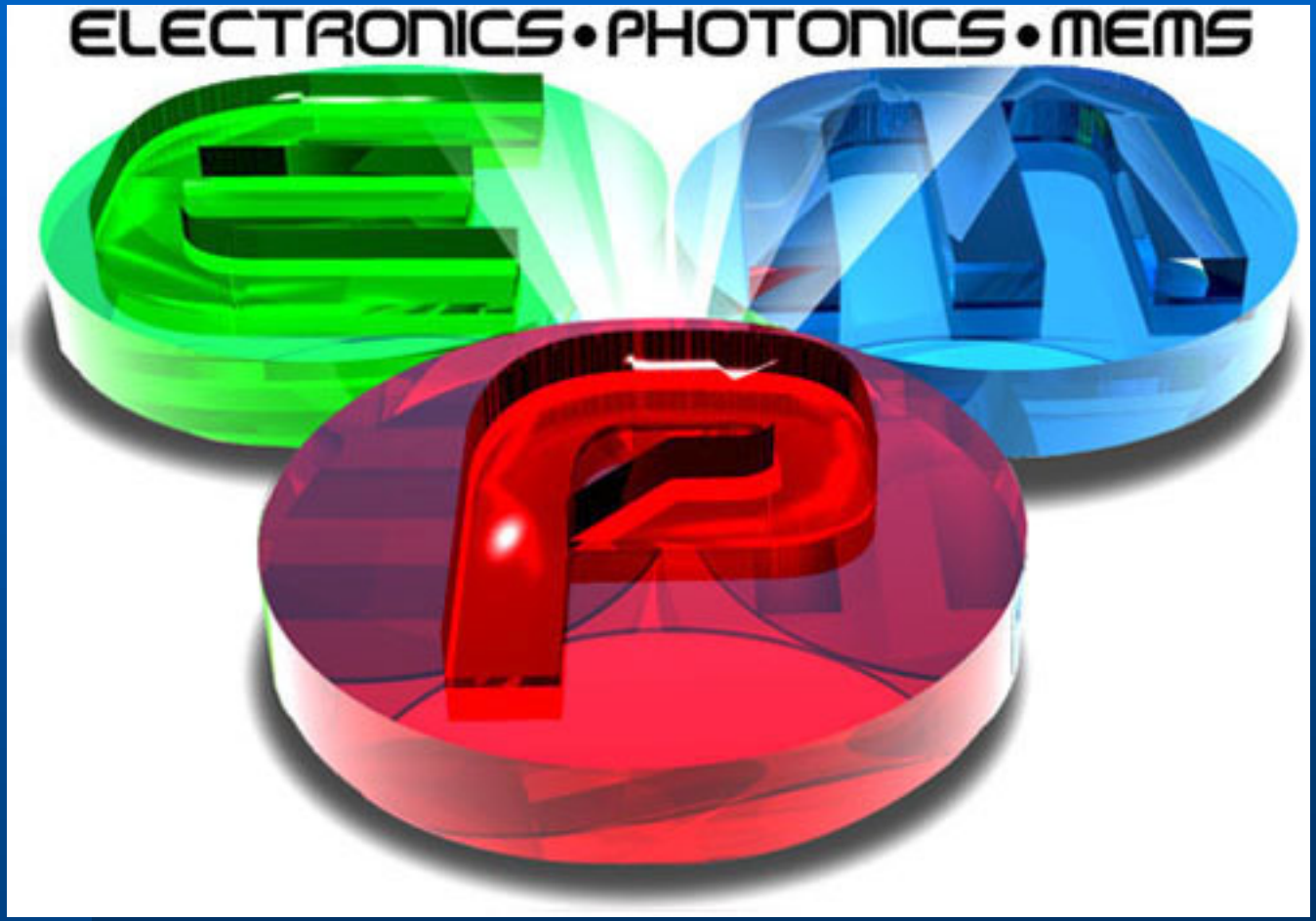
- Introduction
- Current Thrusts
- MEMS Applications in Space
- Conclusion

DARPA Mission

MTO MEMS

Microsystems Technology Office

MTO MEMS



Technology for Chip-Level Integration of E. P. M.

MEMS Application Domains

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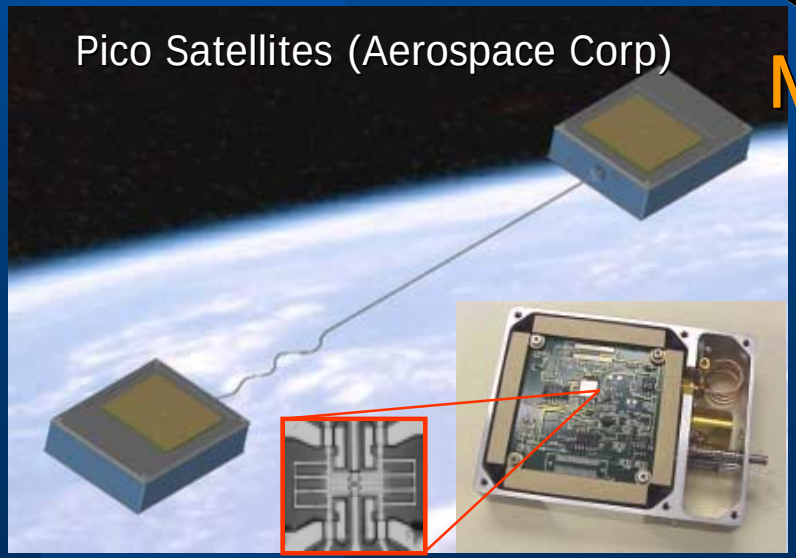
Shear-Stress Sensor for Jet Fighter (Caltech)

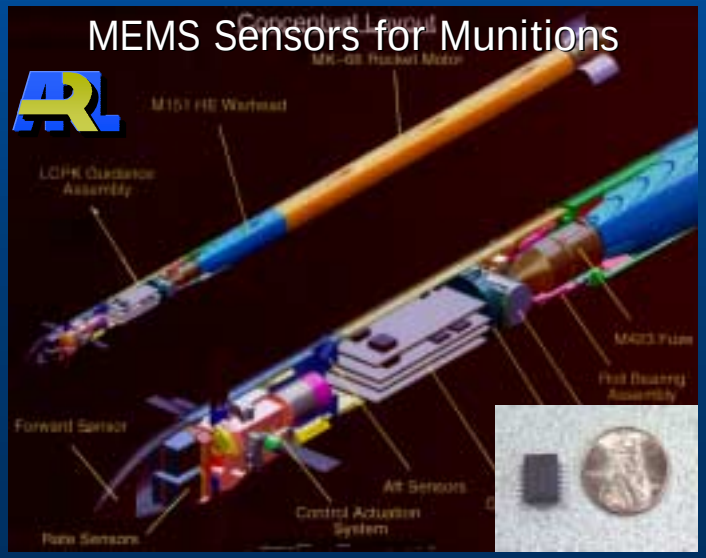
MEMS Exploder for Torpedoes

M E M S

Pico Satellites (Aerospace Corp)



MEMS Sensors for Munitions



Pico Satellite Potential Applications

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- Cooperative constellations
- Sparse aperture antennas
- Inspect and service missions
- Extremely agile launch-on-demand, short-term, survivable and robust communications and surveillance space systems

Picosat Current Technology

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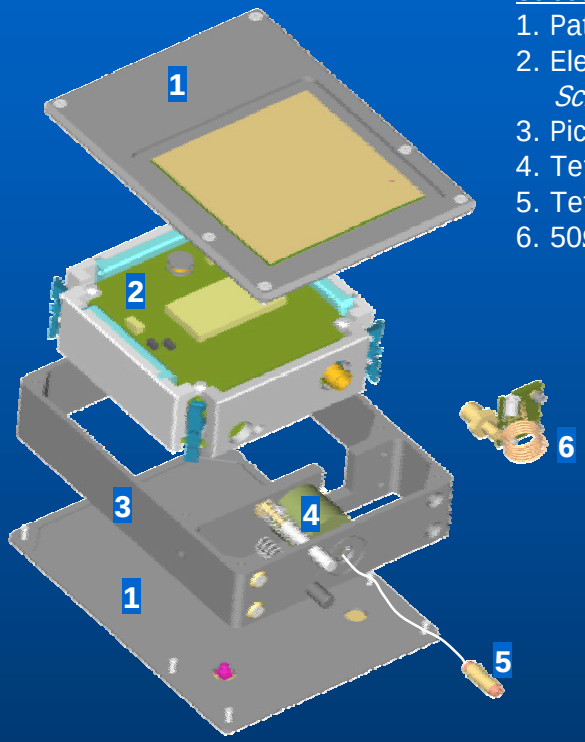
Batteries and Keepers

DC/DC Converter Board

Radio and Sensor Boards

Thermal Isolation Bracket



Subcomponents

1. Patch Antenna Panel
2. Electronics Module with *Rockwell Science Center* Radio and MEMS Switches
3. Picosat Body
4. Tether Spool
5. Tether Coupler
6. 50Ω Splitter Board

Antenna Panel:
Front / Back

50Ω Splitter

Tether Spool,
Flight Configuration

Tether Spool,
Testing

Potential MEMS Components for Future Picosat

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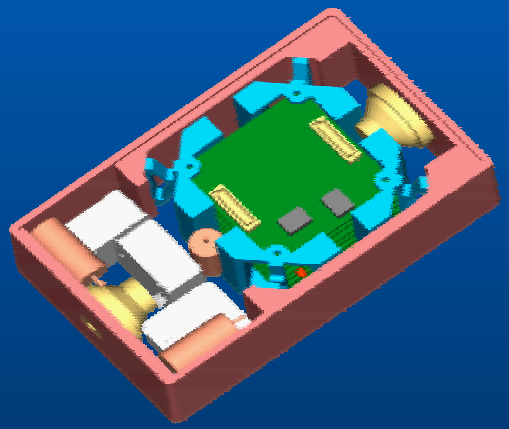
MEMS Navigation

Micro-propulsion

Imager & Sensor



High-density data storage

High energy-density power

RF Communication

MEMS Inertial Sensors

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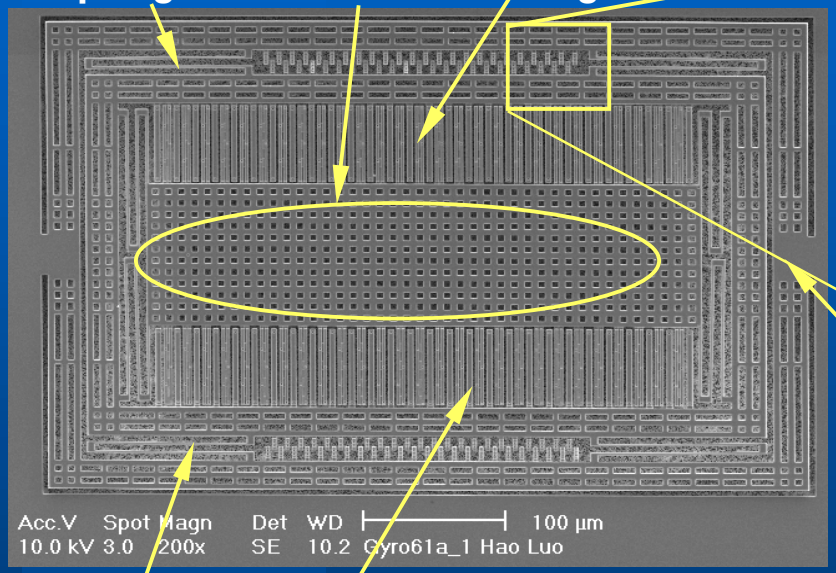
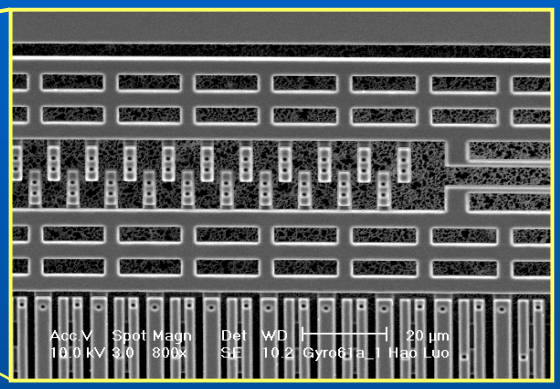
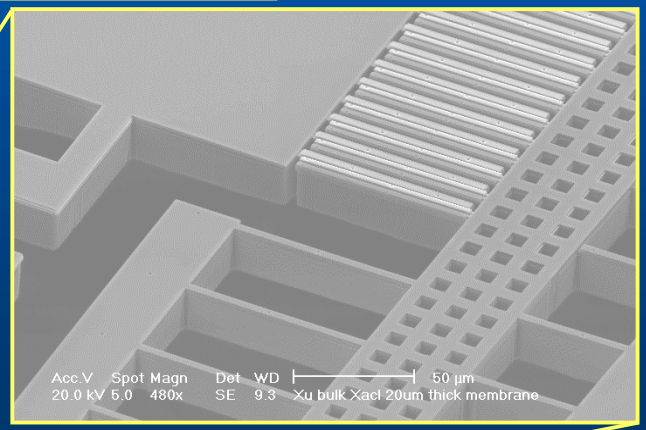
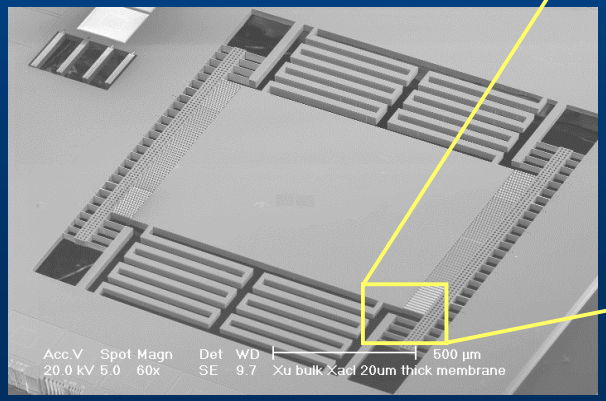


Gyroscope



Anchor





Accelerometer

MEMS Actuators for Data Storage

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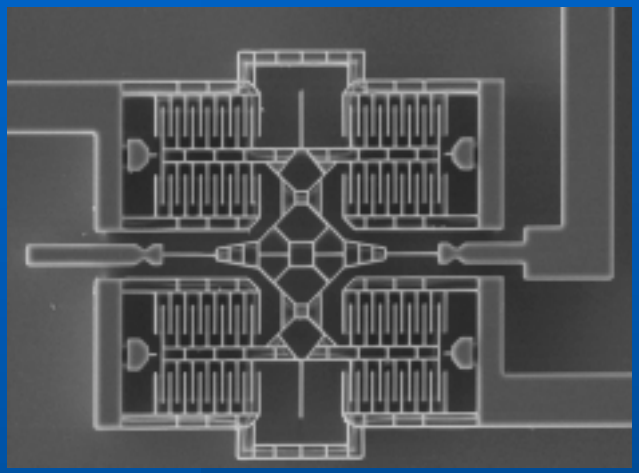
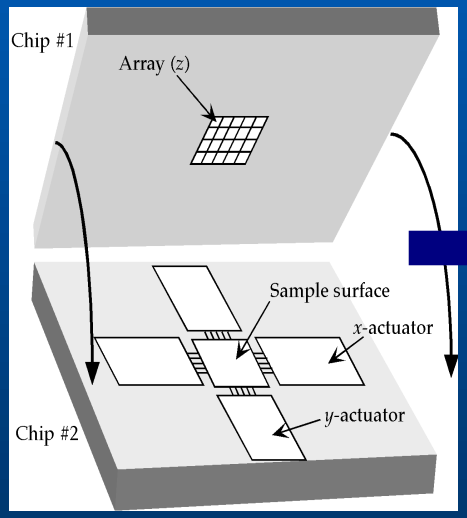
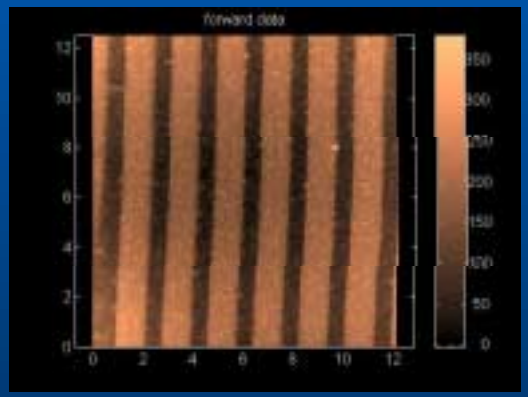
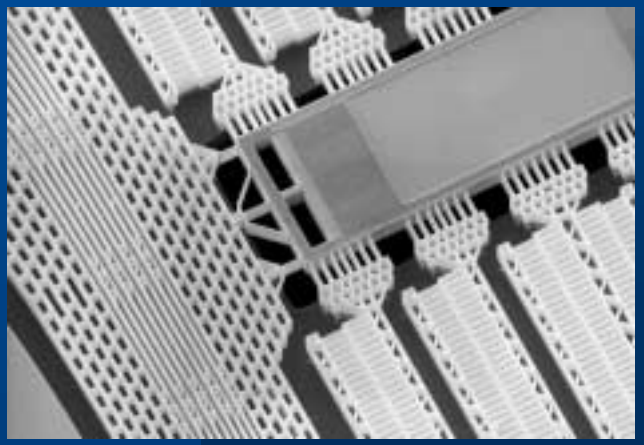


Parallel atomic force imaging with MEMS to exceed densities of conventional magnetic and optical storage







Areal density: 1-100 Gb/cm^2
Transfer Rates: 0.1-10 Mb/s
Size: 0.5 cm^3
Power consumption: <1W

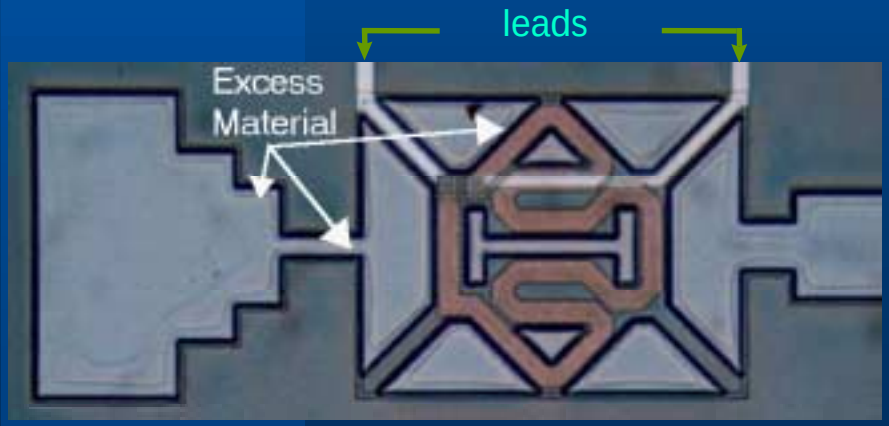
Kionix

Micropropulsion

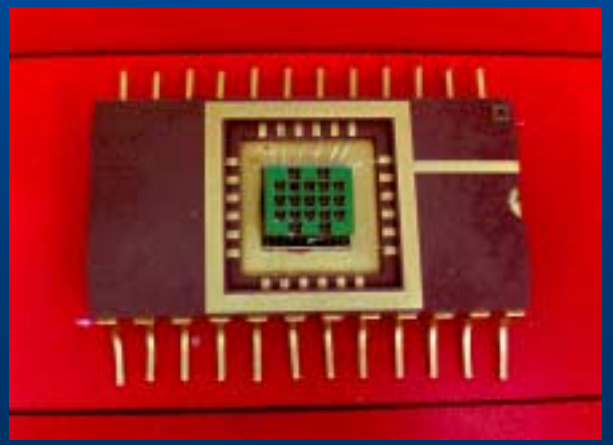
MTO MEMS

Cold gas thruster

2D nozzle in plastic



Microresistojet Thruster



Digital Propulsion Chip

THE AEROSPACE CORPORATION

NMASP Program Goals

MTO MEMS

- Create arrays of precision, nano mechanical structures for RF-signal processing that will achieve
  - >100X reduction in size (80 cm^2 to 0.8 cm^2 or smaller)
  - >100X reduction in power consumption (300 mW to <3 mW)
  - >10X improvement in RF performance (spectral efficiency & bandwidth)
- Future Payoff
  - example: wristwatch-size UHF communicator/GPS receiver

Mechanical Resonators as Filters

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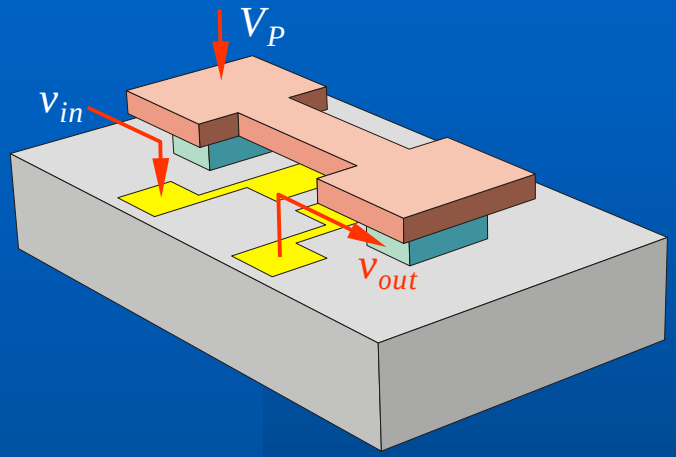

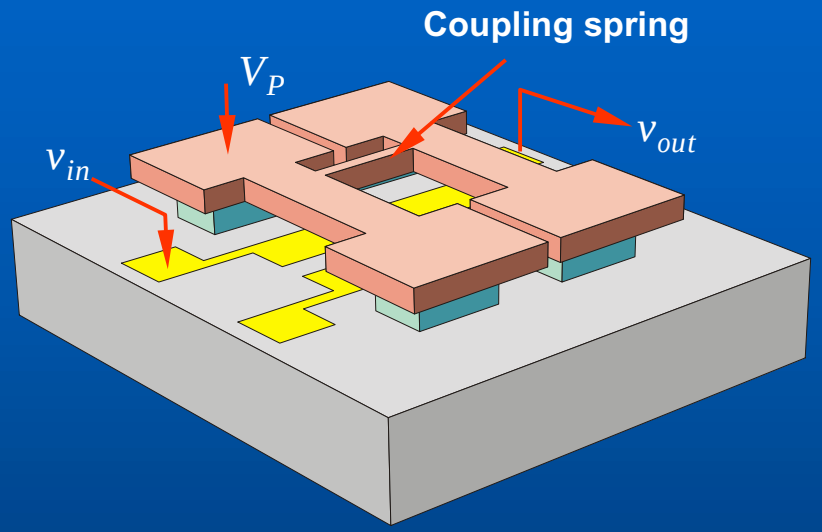

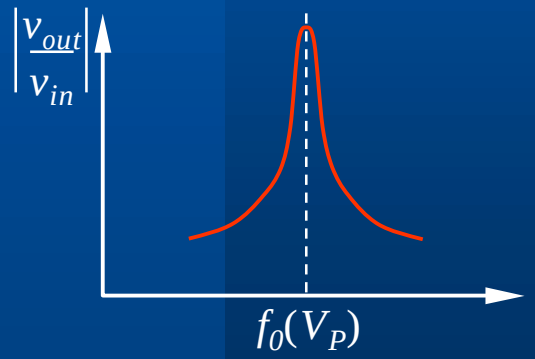

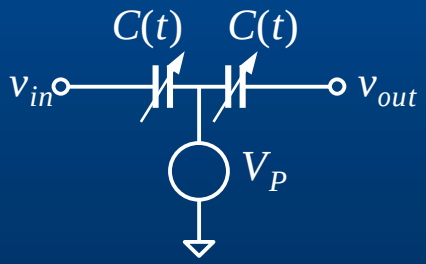

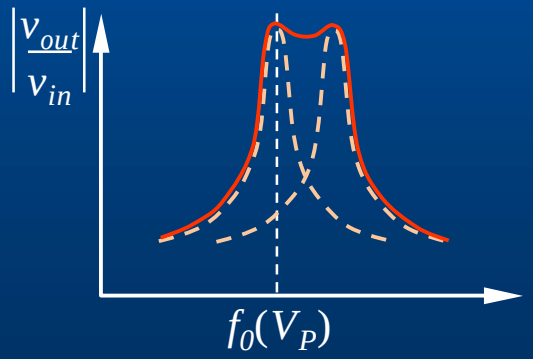

Mechanical Analog Signal Processing

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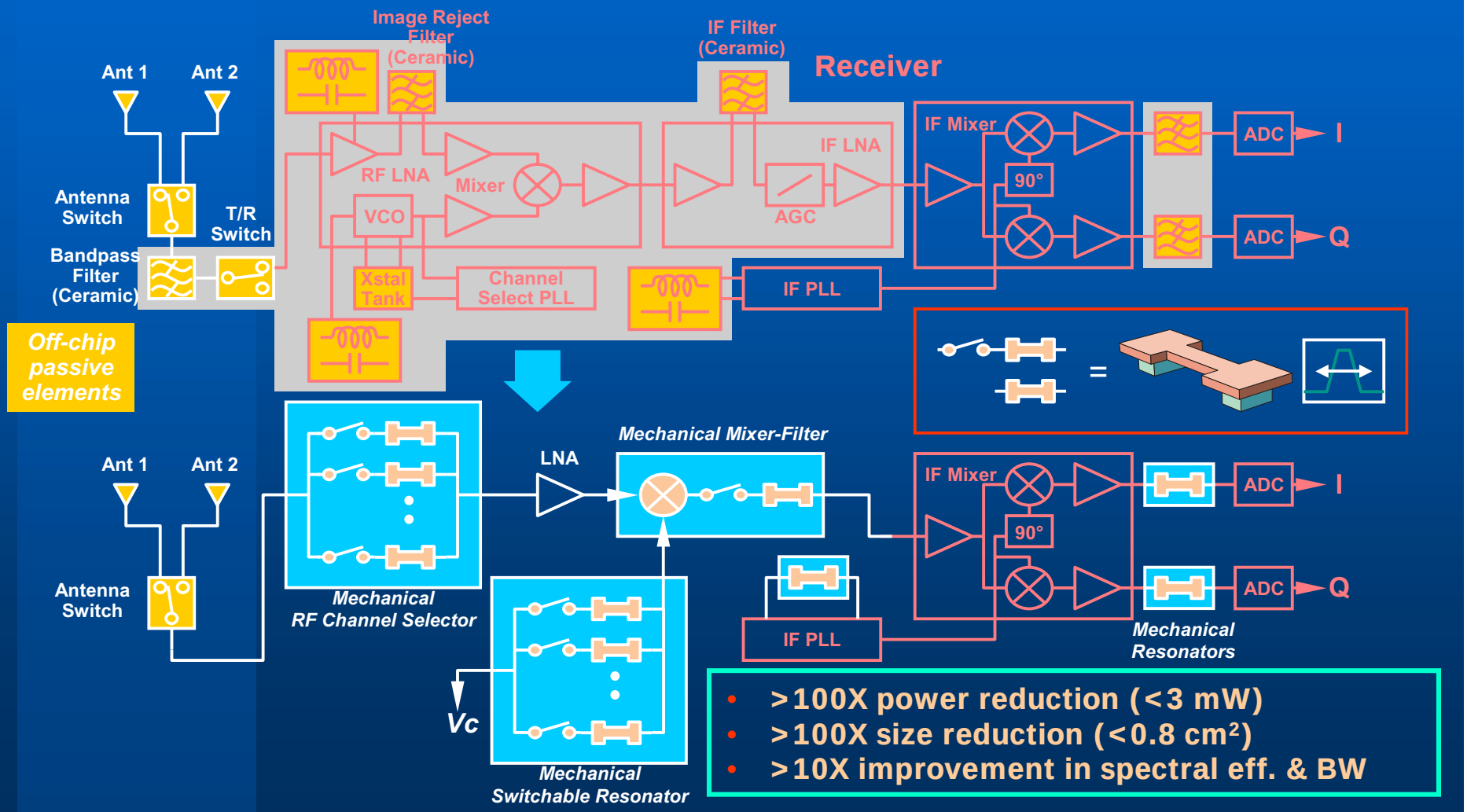

Signal Processing Possibilities

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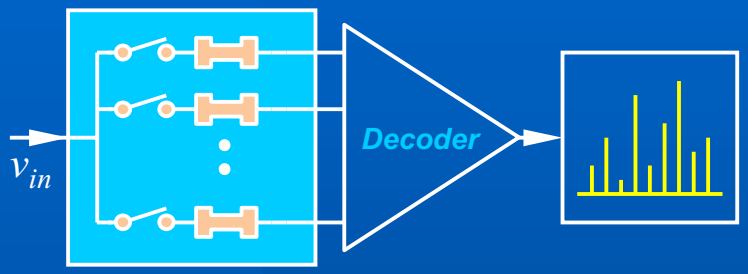
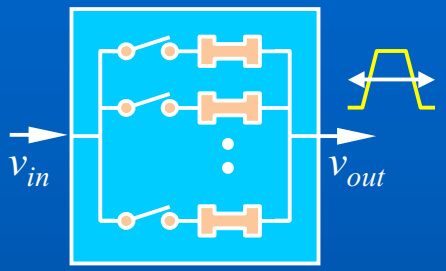
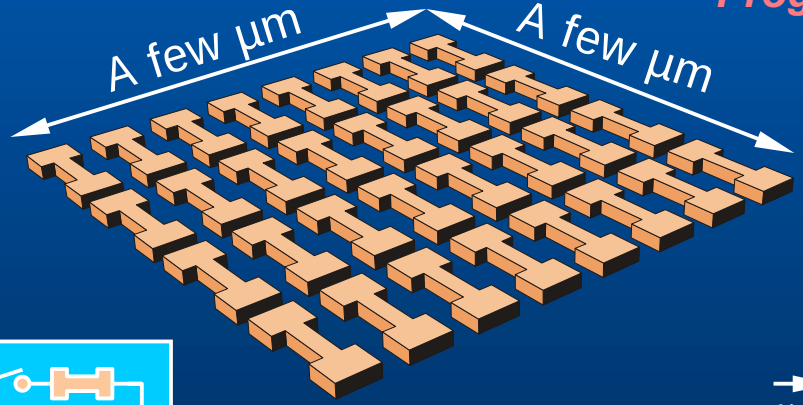
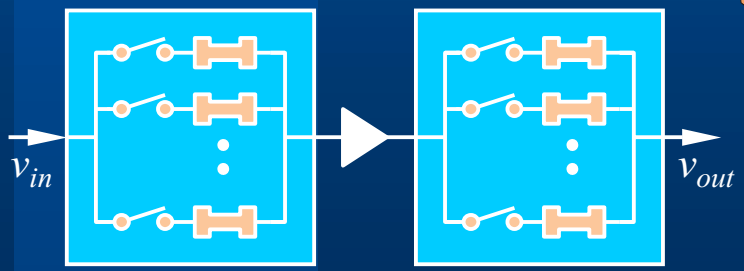


Spectrum Analyzer /
Fourier Signal Transformer

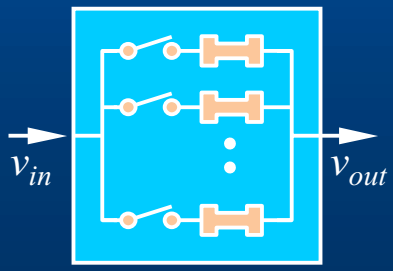


Tracking Filter /
Discriminator /
Programmable Equalizer





Frequency Converter



Parametric Amplifier /
Digital Demodulator /
Envelope Detector

Chip-Scale Atomic Clocks

MTO MEMS

- Create ultra-miniaturized, low-power, atomic time and frequency reference units that will achieve:
  - >200X reduction in size (from 230 cm^3 to <1 cm^3),
  - >300X reduction in power consumption (from 10 W to <30 mW), and
  - Matching performance ($\pm 1 \times 10^{-11}$ accuracy $\Rightarrow$ <1μs/day).
- Examples of future payoffs:
  - Wristwatch-size high-security UHF communicator
  - Jam-resistant GPS receiver

CSAC Miniaturization Concept

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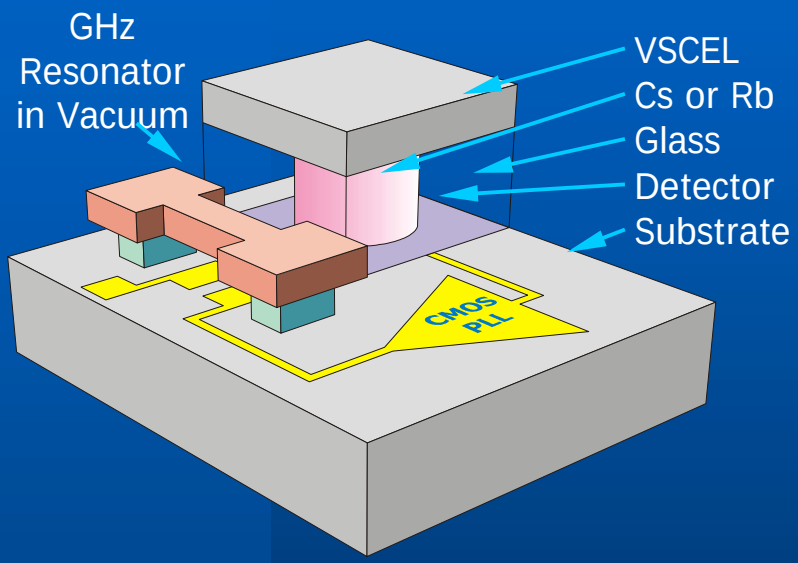

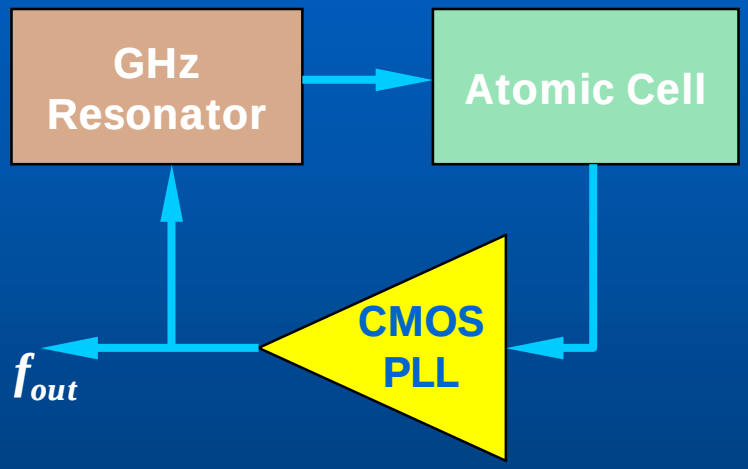

Phase locking GHz resonator with miniature atomic-confinement cell:

- Optical excitation ⇒ use VSCEL, eliminate μ-wave cavity (large & power-hungry)
- Optical detection ⇒ use photo-detector
- Mechanical resonator ⇒ electrostatic and capacitive coupling

Military Applications of CSAC

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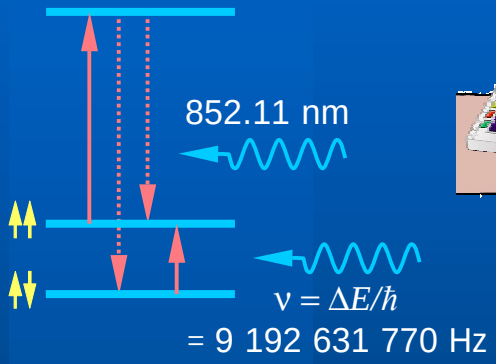

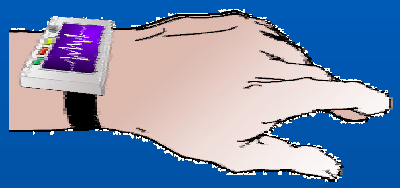

Ultra-miniaturized, low-power, atomic time and frequency reference units:

>200X reduction in size, >300X reduction in power & performance ($\pm 1\times10^{-11}$ accuracy $\Rightarrow$ <1μs/day)

Clock accuracy of $1 \times 10^{-11} \Rightarrow$ 16-hour resynch interval or radio silence

9,000 commercial handheld GPS deployed in Desert Storm

Future of MEMS at DARPA

MTO MEMS

- Continue to establish new MEMS-enabled programs, both within MTO and in collaboration with other offices
- Continue to transition into DoD and commercial systems
  - Formation of the MEMS Industry Group